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The BTeV Experiment: Physics and Detector

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Abstract. Exploring the large number of heavy quarks produced at Fermilab's Tevatron collider, the BTeV experiment is designed to make precision measurements of Standard Model parameters and to perform an exhaustive search for physics beyond the Standard Model. In my presentation at LHC2003 I presented some highlights of the BTeV physics program and discussed a few of the many technological challenges the BTeV collaboration faces designing and building the detector

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1 Introduction

The BTeV collaboration is in the middle of an active research and development program which causes the interesting details of the experiment to change much faster than the time scales typical for the publication of conference proceedings. Acknowledging this fact my report will not provide a detailed discussion of the BTeV detector, the status of B physics in the Spring of 2003 or the BTeV physics program. Instead, I will give a brief description of the major components of the BTeV spectrometer and some of the physics studies but otherwise provide links to more up-to-date information on the World Wide Web. General information about BTeV is available on the collaboration's web site which can be accessed using the URL `http://www-btev.fnal.gov/`. The transparencies of the presentation can be found on the conference web site (`http://vmsstreamer1.fnal.gov/VMS_Site_02/Lectures/LHC2003/Honscheid/index.htm`) or can be downloaded from the author's web site at
`http://www-physics.mps.ohio-state.edu/~klaus/research/talks/lhc2003_btev.pdf`.

2 B Physics at Hadron Colliders

Most of our current knowledge on B mesons and their decays comes from experiments performed at electron positron colliders. Recent results further constrain the elements of the Kobayashi-Maskawa quark mixing matrix (CKM) and the success of the B-factories at KEK and SLAC has led to the observation of CP violation in the B meson system. To date no conflict with the Standard Model has been reported. The physics of B mesons, however, had had its share of surprises (long lifetime, B-$\bar{B}$ oscillation) and in order to confirm - or to go beyond - the Standard Model description of heavy quark decays it is necessary to embark on a program to measure all CKM elements and all CP phases with high precision. Several orders of magnitudes more B meson decays than are available in today's data samples will be required for this effort. Compared to e^+e^- machines the b production cross section is much larger at a hadron collider. Unfortunately, the total inelastic cross section is even larger so that the signal to background ratio (the b fraction) at a hadron collider detector becomes quite unfavorable (see Table 1). Given the poor signal to background ratio the single most impor-

	Tevatron	LHC
Energy	2 TeV	14 TeV
b cross section	100 μb	500 μb
c cross section	100 μb	300 μb
b fraction	2×10^{-3}	6×10^{-3}
Inst. luminosity	2×10^{32}	10^{33} - 10^{34}
Bunch spacing	396 ns (132 ns)	25 ns
Int./crossing	¡6¿ (¡2¿)	¡1¿
Luminous region	30 cm	5.3 cm

Table 1. Some key parameters for B experiments at hadron colliders

tant component for a B experiment at a hadron collider is the trigger. Other detector requirements include a high resolution vertex detector for decay length measurements and time dependent studies, excellent particle identification over the entire momentum range and an electromagnetic calorimeter to reconstruct photons and π^o's that are present in most B decays. A multi-purpose, high $p_\perp$ experiment requires large solid angle coverage but for a dedicated B experiment such as BTeV it is advantageous to use a forward, spectrometer-like geometry:

- significantly lower costs.
- easy access to all detector components
- the large Lorentz boost in the forward/backward direction increases the reconstruction efficiency for B decays and improves the proper time resolution.
- strong correlations between $b\bar{b}$ production angles significantly improve flavor b tagging efficiencies.

3 The BTeV Detector

A schematic view of the detector is shown in Figure 1. The geometry is complementary to that used in current collider experiments. Instead of the central region the spectrometer covers only the forward direction, 10 - 300 mrad, with respect to the colliding beams.

Charged particle tracking and vertexing is accomplished by a combination of a silicon pixel vertex detector and a forward tracker. The pixel detector will contain approximately 3×10^7 rectangular pixels, each 50 μm $\times$ 400 μm, connected to a custom designed read-out circuit by a "bump bond". The pixel detector is arranged in 31 stations each consisting of two 10 cm $\times$ 10 cm planes. A 12 mm $\times$ 12 mm hole is cut out for the colliding beams. Details of the BTeV pixel detector and the custom designed readout electronics can be found at `http://www-btev.fnal.gov/public/hep/detector/pixel/index.shtml`. The forward tracker consists of 4-mm diameter straw tube driftchambers and silicon strip detectors in the high occupancy areas near the beam pipe. Further details are available at `http://www-btev.fnal.gov/public/hep/detector/straw/index.shtml`.

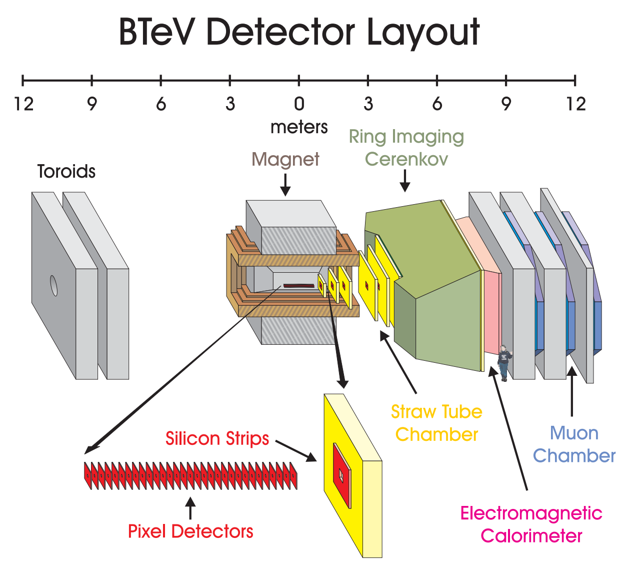

Fig. 1. Schematic view of the BTeV Spectrometer.

Particle identification over a wide momentum range will be provided by ring-imaging Cherenkov counters (RICH). Access `http://www-btev.fnal.gov/public/hep/detector/rich/index.shtml` for more information on the BTeV RICH detector.

The BTeV design includes an electromagnetic calorimeter for photon and neutral pion reconstruction as well as electron identification. The BTeV calorimeter will be built using $PbWO_4$ crystals, very similar to the CMS calorimeter. Detailed information on the design. performance and readout of the BTeV EM calorimeter is available at `http://www-btev.fnal.gov/public/hep/detector/emcal/index.shtml`

The BTeV muon detector provides independent momentum measurements for muon candidates using two 1 m long steel toroid magnets at 1.5 T. The active detection planes are built out of stainless steel proportional tubes (`http://www-btev.fnal.gov/public/hep/detector/muon/index.shtml`).

Of central importance to the BTeV physics program is the detached vertex trigger. Using information from the silicon pixel detector this trigger searches every beam crossing for detached vertices, the characteristic signature of b quark decays. This first level trigger together with higher trigger levels and a high performance data acquisition system will give BTeV high efficiency for interesting b decays combined with excellent background suppression. Further information on the trigger and data acquisition systems can be found at:
`http://www-ese.fnal.gov/eseproj/trigger/web/default.htm` and
`http://www-physics.mps.ohio-state.edu/~klaus/research/talks/rt2003_btev.pdf`.

4 The Physics Goals

Over the years many experimental observations have demonstrated the need for New Physics, *i.e.* physics beyond the Standard Model. The baryon asymmetry of the universe, dark matter, the hierarchy problem, the plethora of fundamental parameters to name just a few. The BTeV experiment is well positioned to search for New Physics via rare decays and via CP violating phases. It will perform precision measurements of CKM elements with small model dependence. In addition, the BTeV collaboration will complete a broad program in heavy flavor physics including semileptonic transitions, B_s, Λ_b and B_c decays and b spectroscopy. A detailed description of the BTeV physics potential can be found on the BTeV web site at
`http://www-btev.fnal.gov/public/hep/general/proposal/index.shtml`. Updated reviews can be found at the P5 web site (`http://doe-hep.hep.net/p5/agenda0303.html`) and at
`http://www-physics.mps.ohio-state.edu/~klaus/research/talks/cipanp.ppt`.

5 Summary

Heavy quark physics at hadron colliders provides a unique opportunity to measure fundamental parameters of the Standard Model with no or only small model dependence, to discover New Physics in CP violating amplitudes or rare decays, and to interpret new phenomena found elsehwere, e.g. at the LHC. Some scenarios are clear today - others will be a surprise. This program requires a general purpose detector with an efficient, unbiased trigger and a high performance DAQ system, a superb charged particle tracking system combined with good particle identification and excellent photon detection. This program requires the BTeV experiment.